Investigating the effects of orography and ambient wind on deep convection over tropical islands

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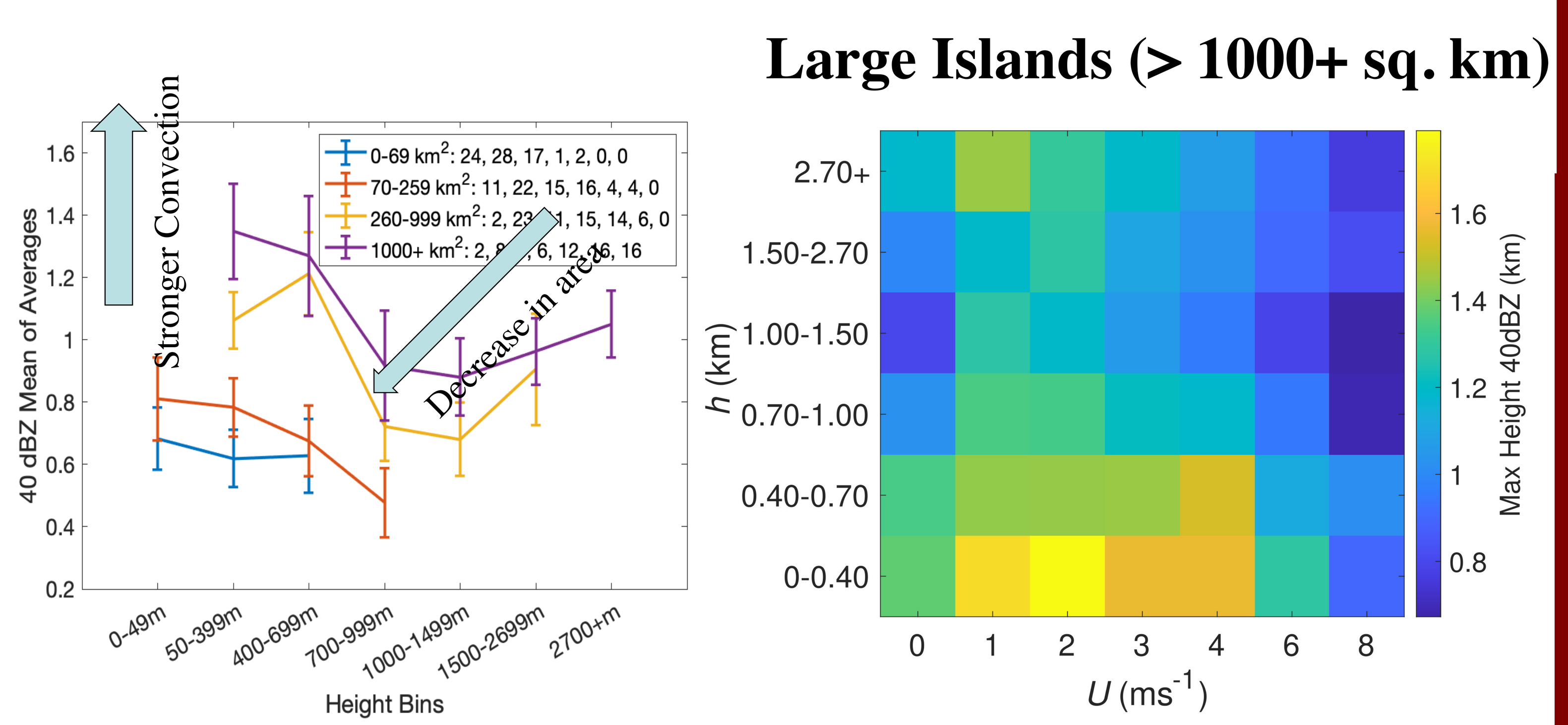
Abstract

An analysis of the Tropical Rainfall Measuring Mission (TRMM) satellite database (1994-2015) of 280 tropical islands, shows an overall weakening of convection with increase in either peak island elevation (h) or surface wind speed (U), for a given island size (A).

The key metric determining convective vigor is the area of the pre-convective CAPE over the island, which is diminished by higher orography and stronger winds and smaller islands, thus explaining all three observed trends.

Why doesn't orography promote convection, rather than inhibiting it?

Analysis of radar retrievals from the Tropical Rainfall Measuring Mission over 280 islands from 1998-2015 reveals a weakening of convection with (i) increase in island peak height, h (ii) increase in ambient wind speed, U and (iii) decrease in island area



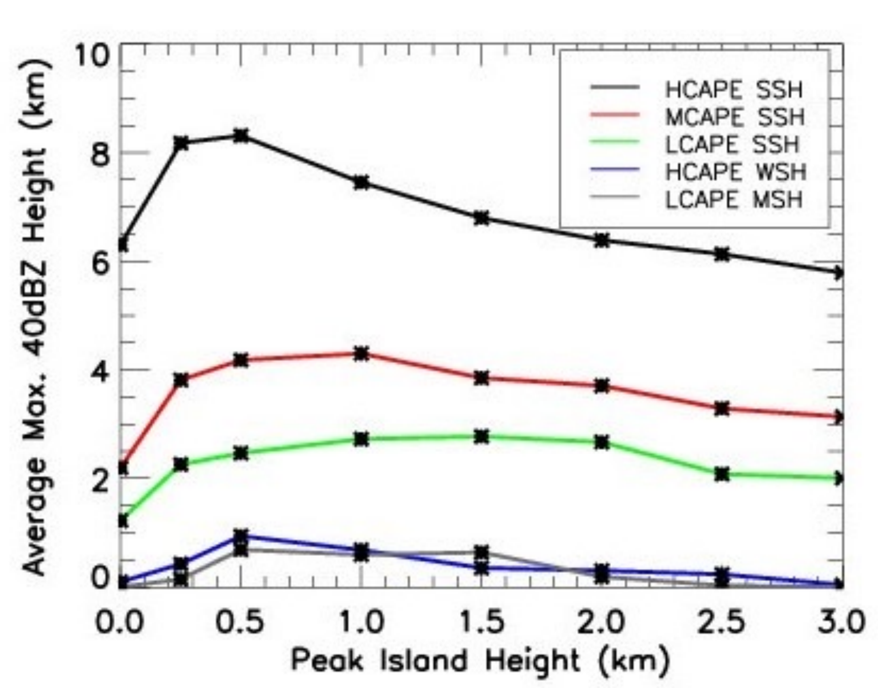
Exploratory WRF Simulations

WRF 4.4.2; Diurnal flux; Realistic orography, 3D, 2km horizontal resolution, 60m < dz < 1.3km, sinusoidal sensible and latent heat fluxes, Morrison Microphysics, boundary layer parametrization

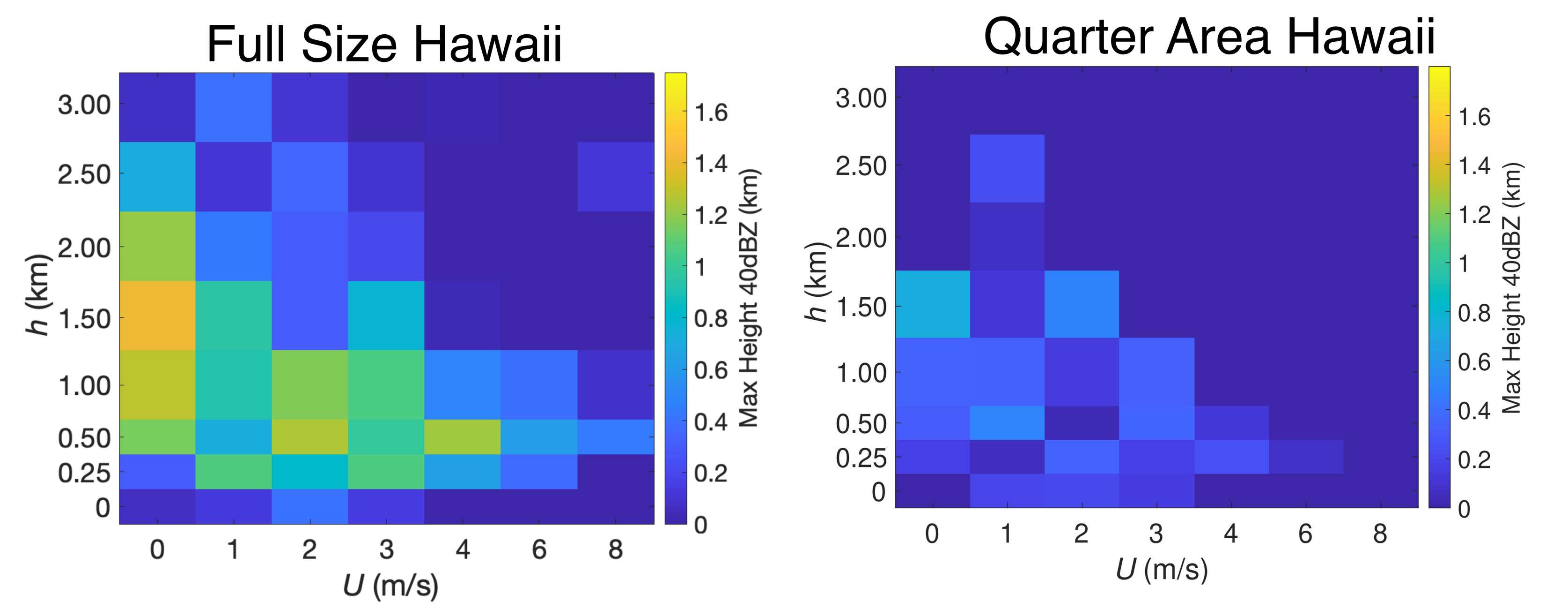
CAPE (J/kg) of 170 (LCAPE), 350 (MCAPE) & 1050 (HCAPE)

Surface heat fluxes (W per sq. m): 20 (WSH), 60 (MSH) & 200 (SSH)

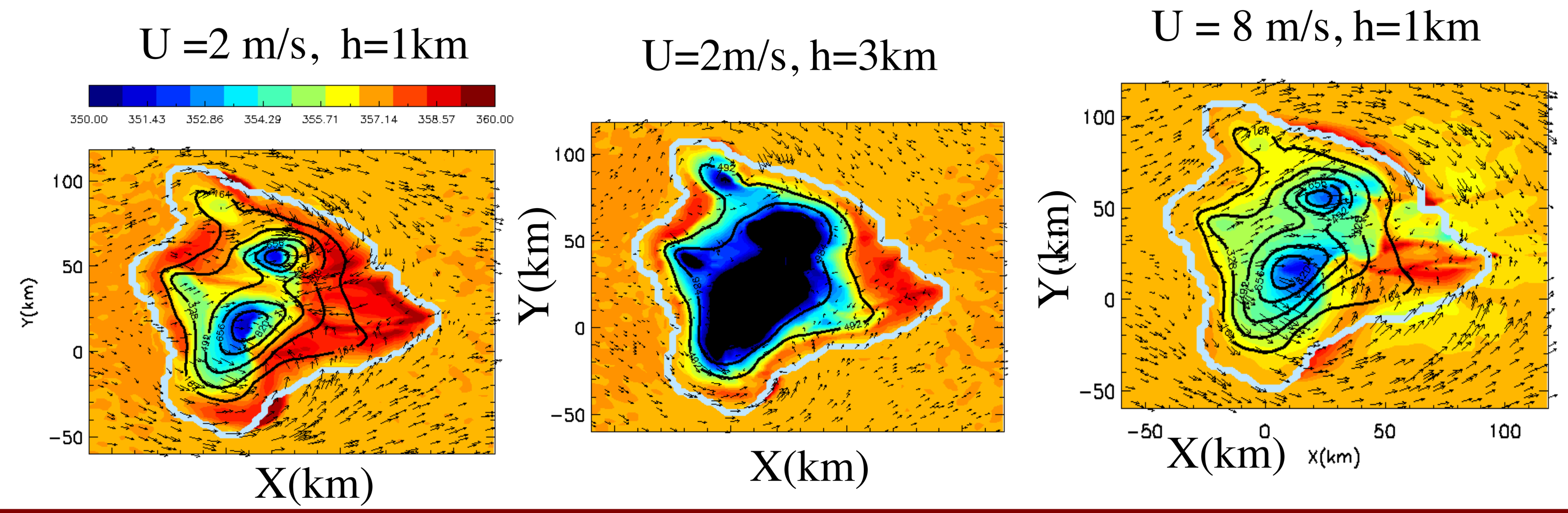
Require weak heating (WSH) and high CAPE (HCAPE) to reproduce magnitude and ~ trend in observations



Simulated 40dBZ proxy for idealized 'Hawaii'

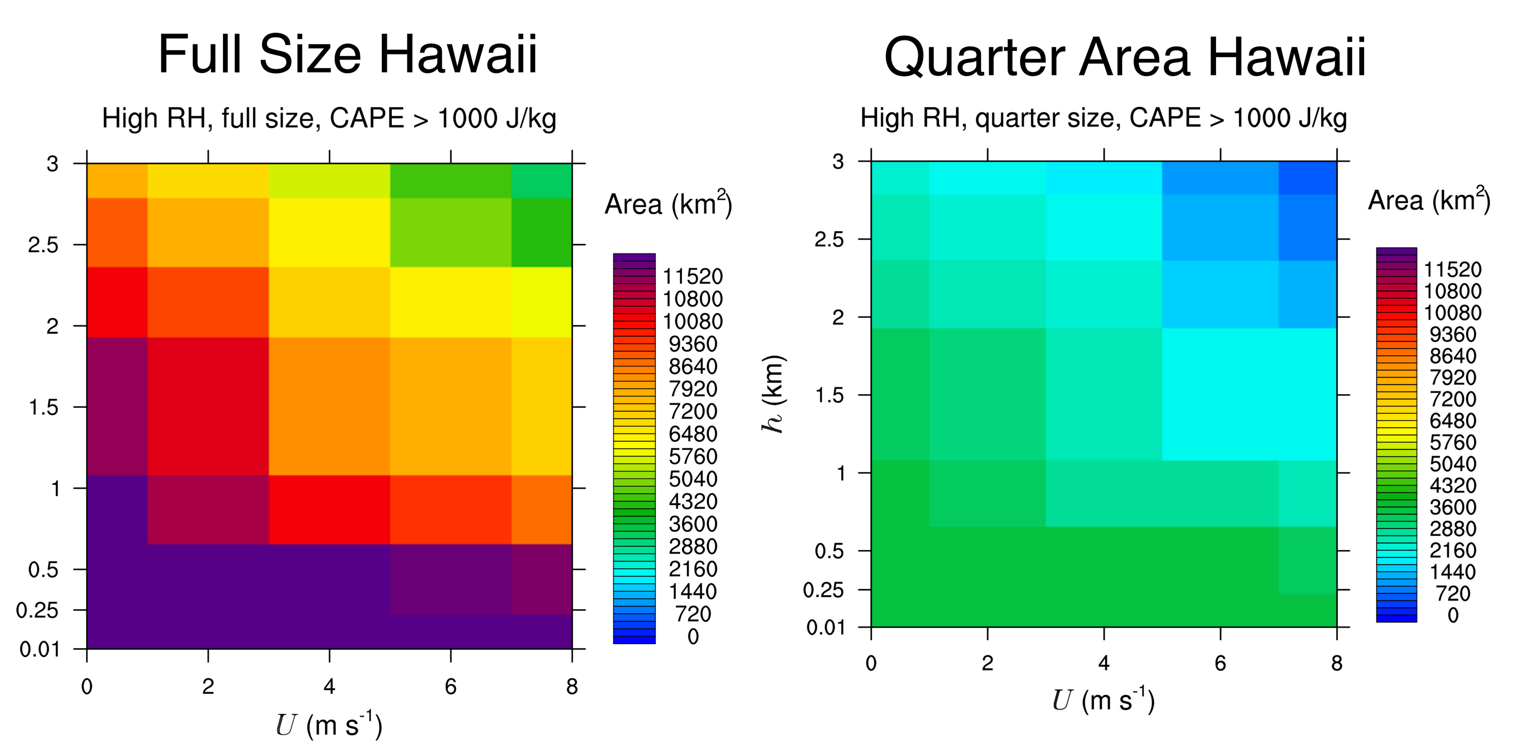


Surface Equivalent Potential Temperature (shown below) drops with increase in U or h



Vigor variation due to area of high CAPE

Area of island with CAPE above 1000 J/kg (3 hours before convection occurs)



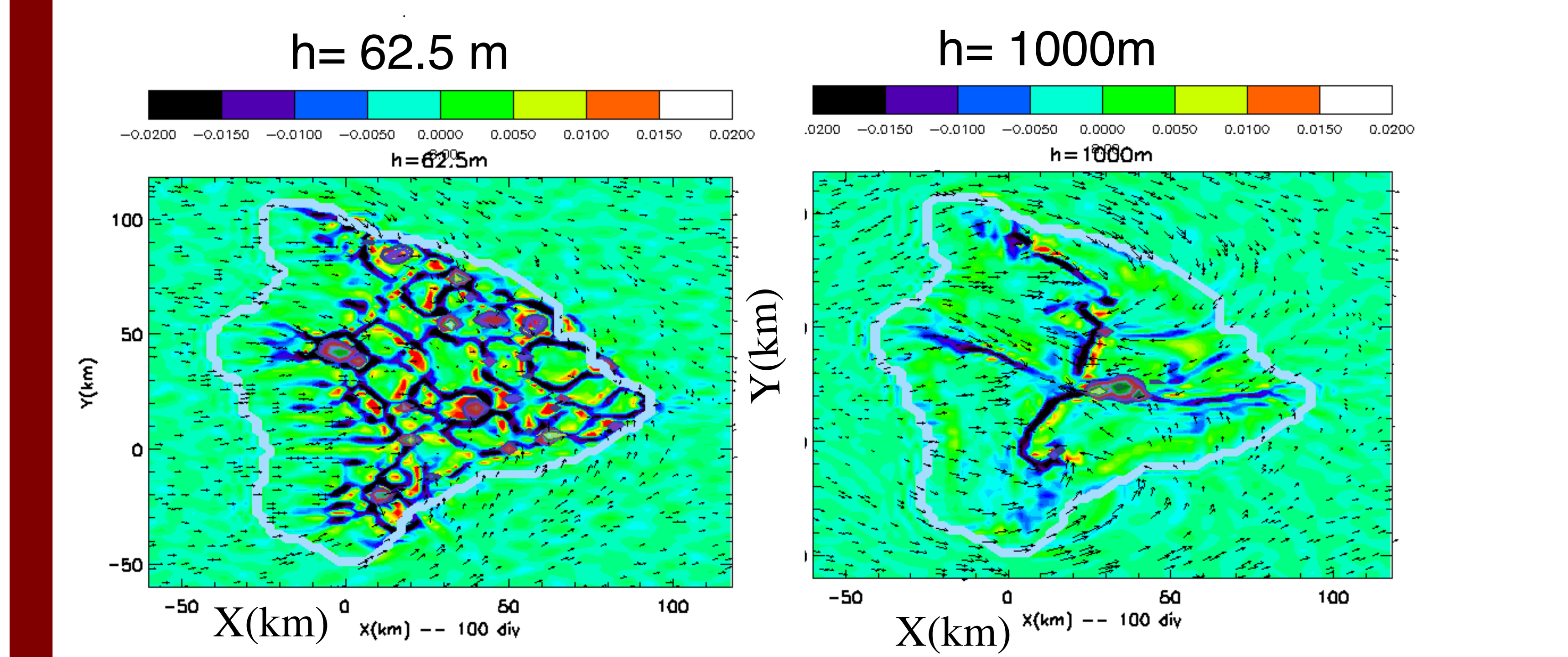
Comparing the above two plots with the max height 40 dBZ U-h plots in previous slide shows that:

Islands with areas of high CAPE above the 1000 J/kg threshold, develop the strongest convection

For small h (< 500m), Convection is weak, even when CAPE > 1000 J/kg

Why does convection weaken for h < 500 m ?

Contours of divergence lines and integrated hydrometeor



Transition from weak to strong convection due to a tilting of the horizontal temperature gradient by the slope of the mountain.

When horizontal temperature perturbation is projected onto a slope, it increases in magnitude due to the vertical temperature stratification, driving stronger convection.

Conclusions and Acknowledgements

1. Observed convection over islands strengthens with island area as found previously, but weakens with greater orography, other things being equal—opposite to expectations from orographic lifting. It also weakens with sufficiently strong U.

2. WRF roughly reproduces these trends but only under certain conditions, namely, weak surface forcing, high CAPE, and at least minimal orography (h > 500m).

3. The behavior is consistent with vigor being controlled by the area of high CAPE.

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WRF Simulations all run on Cheyenne @ NCAR

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